



February 17, 2024

Re: JPH07313649A

To Whom It May Concern:

This is to certify that the above-referenced documents (**390-45767 Japanese-to-English translation of patent JPH07313649A**) have been translated from Japanese into English by a professional translator on our staff who is skilled in the Japanese language.

The English translation conforms essentially to the original Japanese except for those words or phrases for which there are no equivalents. Such words or phrases are noted in the translation along with the best English meaning.

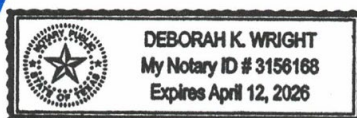
All statements made in this declaration of our own knowledge are true, and all statements made on information and belief are believed to be true. We certify these statements under the understanding that willful false statements and the like are punishable by fine or imprisonment, or both (18 U.S.C. 1001). To the best of our knowledge, the aforementioned documents are a true, full, and accurate translation into English of the specified document.

Tonja Shepard

TONJA SHEPARD

Subscribed and sworn to before me on February 17, 2024.

Deborah K. Wright
Deborah K. Wright
Notary Public, State of Texas



My commission expires on April 12, 2026

(19) Japan Patent Office (JP)

(12) **KOKAI LAID-OPEN
PATENT PUBLICATION (A)**

(11) Patent Application Publication No.
Unexamined Patent Application
No. Hei 7[1995]-313649

(43) Publication date: December 5, 1995

(51) Int.Cl. ⁶ A63B 69/10	Identification Code	JPO File No.	FI	Technical Disclosure
---	---------------------	--------------	----	----------------------

Examination Request: Not requested Number of Claims: 4 OL (total of 7 pages)

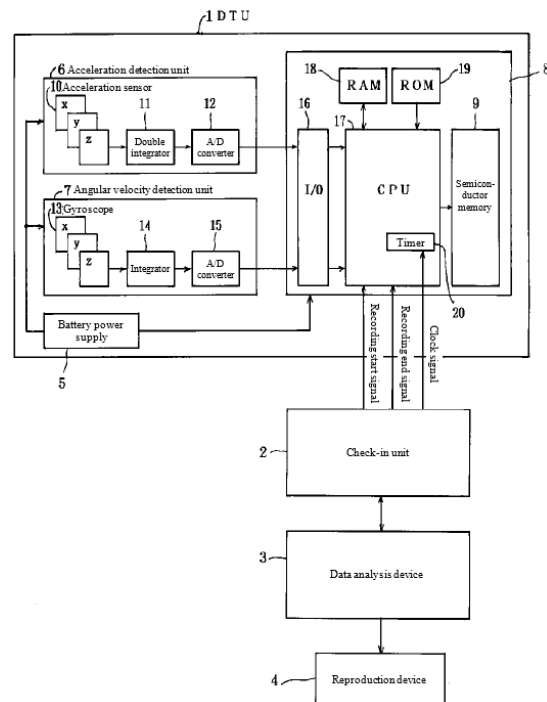
(21) Application No.	Japanese Patent Application No. H6[1994]-114796	(71) Applicant	593077168 Awaji Ferry Boat Co., Ltd. 4-1-1, Sotohama-cho, Suma-ku, Kobe-shi, Hyogo
(22) Application Date	May 27, 1994	(72) Inventor	Yuichiro Yamawaki c/o Awaji Ferry Boat Co., Ltd. 4-1-1, Sotohama-cho, Suma-ku, Kobe-shi, Kobe
		(72) Inventor	Yasumoto Tsuji c/o Awaji Ferry Boat Co., Ltd. 4-1-1, Sotohama-cho, Suma-ku, Kobe-shi, Kobe
		(74) Representative	Shizuo Sano, patent attorney

(54) [Title of the Invention] **MOBILE DATA COLLECTION DEVICE FOR UNDERWATER MOVING BODY AND
DIVING TRAINING SYSTEM COMPRISING SAID DEVICE**

(57) [Abstract]

[Object] To enable accurate reproduction of a diving path diving.

[Configuration] Prior to a diver diving while carrying a mobile data collection device, the diver places a DTU (tracking unit) 1 on a check-in unit 2, to initialize the DTU 1 to start recording data, and then starts swimming. The diver's movement while swimming is detected by a 3D3D acceleration sensor 10 and a 3D3D gyroscope 13 of the DTU 1. Detection values from the sensors falling within a preset micro value range are not recorded in a semiconductor memory 9, with only significant detection data outside that range being recorded. The data acquired by the DTU 1 thereafter until a final checkout operation is analyzed by a data analysis device 3 as certified significant data, and, based on the processed data, the full diving path is displayed and reproduced chronologically and dynamically on a 3D3D map in a reproduction device 4.



[CLAIMS]

[Claim 1] A mobile data collection device for an underwater moving body, wherein a device body is provided with: a battery power supply, a 3D acceleration sensor for detecting acceleration of a moving body during underwater movement; a 3D gyroscope for detecting rotation velocity of the moving body during underwater movement; a semiconductor memory backed up by the battery power supply; and a control means for recording the output values detected by the 3D acceleration sensor and the 3D gyroscope in the semiconductor memory as 3D movement data of the moving body during underwater movement, in cases where the detection output of the 3D acceleration sensor and the 3D gyroscope does not exceed a preset micro value range.

[Claim 2] The mobile data collection device for an underwater moving body according to Claim 1, wherein the device body can be worn and removed by a diver.

[Claim 3] The mobile data collection device for an underwater moving body according to Claim 1, wherein the control means is provided with functionality to chronologically record in the semiconductor memory 3D movement data needed to display a 3D path of the diver after a dive, together with the time at which the data was provided.

[Claim 4] A training system for diving, comprising: the mobile data collection device for an underwater moving body according to Claim 3; a data analysis device, which can be electrically connected to the mobile data collection device and analyzes the 3D movement data recorded in the semiconductor memory of the mobile data collection device; and a reproduction device for displaying and reproducing a full diving path chronologically and dynamically on a 3D map based on the processing by the data analysis device.

[DETAILED DESCRIPTION OF THE INVENTION]

[0001]

[Industrial Applications] The present invention relates to a data collection device for recording the movement path of an underwater moving body as electrical data, and to a diving training system, which includes a mobile data collection device for an underwater moving body that is capable of accurately plotting a diver's swimming path as recorded by the device on a background screen represented by a nautical chart or computer graphics.

[0002]

[Prior Art] In recent years, diving with an aqualung (trademark) has become popular, but divers engage in underwater diving which always entails danger due to the effects of ocean currents and water depth, thus making it essential for beginners to receive training. In addition, even those divers who have mastered basic diving techniques require training in order to master more advanced diving techniques.

[0003] Such diving training is conducted in a suitable maritime zone, and when carrying out the training, it is important to accurately identify the diver's swimming path in order to maximize the effectiveness of the training. To that end, it is necessary to display the diver's swimming path graphically after the dive, but instructors or divers themselves have no choice but to recall the path after the dive and reproduce it graphically based on their recollection thereof.

[0004]

[Problem to Be Solved by the Invention] However, even in the case of diving in a specific maritime zone as described above, diving in water involves 3D movement due to the addition of diving depth on top of 2D movement in a plane within the maritime zone. Moreover, the sense of distance underwater is quite

different from that on land, making it extremely difficult for divers or their instructors to accurately indicate the path taken by the divers graphically after the dive, creating a demand for fundamental improvements to address this problem.

[0005] The present invention has been devised in light of the above problems, and has as an object to provide a portable, user-friendly, and inexpensive mobile data collection device for an underwater moving body and a diving training system capable of accurately reproducing a movement path by analyzing data with a computer after a dive.

[0006]

[Means to Solve the Problem] In order to achieve this object, a mobile data collection device for an underwater moving body according to the present invention is such that a device body is provided with: a battery power supply, a 3D acceleration sensor for detecting acceleration of a moving body during underwater movement; a 3D gyroscope for detecting rotation velocity of the moving body during underwater movement; a semiconductor memory backed up by the battery power supply; and a control means for recording the output values detected by the 3D acceleration sensor and the 3D gyroscope in the semiconductor memory as 3D movement data of the moving body during underwater movement, in cases where the detection output of the 3D acceleration sensor and the 3D gyroscope does not exceed a preset micro value range.

[0007] In the mobile data collection device for an underwater moving body provided with the above configuration, the device body can be worn and removed by a diver, and the control means is provided with functionality to chronologically record in the semiconductor memory 3D movement data needed to display a 3D path of the diver after a dive, together with the time at which the data was provided.

[0008] Furthermore, the diving training system according to the present invention comprises a mobile data collection device for an underwater moving body having the above configuration; a data analysis device which can be electrically connected to the mobile data collection device and analyzes the 3D movement data recorded in the semiconductor memory of the mobile data collection device; and a reproduction device for displaying and reproducing a full diving path chronologically and dynamically on a 3D map based on the processing by the data analysis device.

[0009]

[Effects] According to the mobile data collection device for an underwater moving body having the above configuration, the movement of the underwater moving body is detected by an acceleration sensor and a gyroscope. The detection values from each sensor are recorded in a semiconductor memory via the control means. However, recording all the values detected by the sensors, including values of 0 or micro values, would require a large-capacity semiconductor memory. Therefore, the control means is configured not to record in the semiconductor memory any sensor detection values that fall within a preset micro value range, but rather to record only significant detection data outside that range, thereby making it possible to make the device compact and small and to enable the recording of underwater movement path data over relatively long periods of time.

[0010] If configured to be carried by the diver, this collection device can be used as part of a diving training system. Furthermore, because the control means has a function for recording data chronologically, the 3D movement data needed to display the 3D path after the dive can be recorded chronologically and very

accurately, including the time at which the data was provided. The diver's underwater movement path can be faithfully reproduced as well.

[0011] According to the tracking system having the above configuration, before a diver a dives while carrying the mobile data collection device, check-in and check-out operations are performed at the start and end of recording to trigger the start and end of data recording, with the check-in operation being used to initialize data processing in the mobile data collection device. Subsequently, the data acquired by the collection device up until the check-out operation is performed at the end is analyzed by the data analysis device as certified significant data , and the full dive path can be displayed and reproduced chronologically and dynamically on a 3D map based on the processed data.

[0012]

[Embodiment] An embodiment in which the present invention is applied to a diving training system is described below with reference to the drawings. Figure 1 is a block diagram of an overall configuration of the diving training system according to this embodiment. Figures 2 and 3 schematically show the mechanical configuration of one part thereof. In these drawings, 1 is a tracking unit (hereafter referred to as DTU, which stands for Diver Tracking Unit) as a mobile data collection device for an underwater moving body, 2 is a check-in unit, 3 is a data analysis device, and 4 is a reproduction device with a display such as CRT or electroluminescent panel.

[0013] With the system provided with these devices 1 to 4, the 3D movement data of a diver during a dive collected by the DTU 1 is analyzed by the data analysis device 2, and, based on that analysis, the full dive path is displayed and reproduced chronologically and dynamically in the 3D map on the display of the reproduction device 4.

[0014] Specifically, the DTU 1 is a portable device in which a device body 1a, which makes up an outer housing thereof, is configured to have a relatively high degree of watertightness, with all components compactly accommodated in the device body 1a, which can be worn in an appropriate place on the diver's body and can be removed, and detects the movement distance and movement direction of the diver.

[0015] Inside the device body 1a of the DTU 1 is provided a battery power supply 5 comprising a rechargeable battery or the like, an acceleration detection unit 6, an angular velocity detection unit 7, an intelligent computer 8 serving as the control means, and a semiconductor memory 9 which is backed up by the battery power supply 5.

[0016] The acceleration detection unit 6 incorporates an A/D converter 12, a double integrator 11, and a 3D acceleration sensor 10 which comprises a gyro sensor and detects acceleration during underwater movement of the diver as a moving body. Similarly, the angular velocity detection unit 7 incorporates an A/D converter 15, an integrator 14, and a 3D gyroscope 13 which comprises a gyro sensor and detects the rotational velocity of the diver during underwater movement. The diver's position can be identified accurately by processing the data from the acceleration detection unit 6, and the diver's rotation (direction of travel) can be identified accurately by processing the data from the angular velocity detection unit 7.

[0017] The computer 8 is also provided with an I/O port 16 for the acceleration detection unit 6 and the angular velocity detection unit 7, a CPU 17, RAM 18 that serves as a work area for recording operations of the CPU 17, and ROM 19 that stores programs required for operation of the CPU 17. The CPU 11 is also provided with a timer 20 as software, capable of chronologically recording in the semiconductor memory 9

data with time added to the movement distance calculated based on the continuously changing acceleration data and angular velocity data .

[0018] As shown in Figure 3, the check-in unit 2 is provided to perform check-in and check-out operations at the start and end of recording in order to trigger the start and end of recording of dive data during a dive, formed as a counter and mounted in a position corresponding to the display unit provided to the reproduction device 4.

[0019] A mounting unit 21 of the DTU 1, a start button 22, and an end button 23 are provided on the top surface of the check-in unit 2. When the DTU 1 is mounted in the mounting unit 21 in a prescribed orientation, the DTU 1 is electrically connected. This initializes the DTU 1 at the start of a dive, and sends a data recording end process to the DTU 1 at the end of a dive.

[0020] The data analysis device 3 comprises a computer which performs follow-up analytical processing of the dive data collected by the DTU 1, overlays the data on a 3D map on the computer which has been measured and created in advance, and fully displays and reproduces the diver's dive path in the display of the reproduction device 4. The diver's dive path is not limited to being displayed in a display, but rather can be printed on a maritime chart or otherwise be used with various other types of display means in current use.

[0021] Next, practical operation of the diving training system having the above configuration is described. First, the gist of the operation involves the following five-step procedure:

- ① The DTU 1 is placed on the mounting unit 21 of the check-in unit 2 in a prescribed orientation, and, once mounted, the start button 22 is pressed.
- ② The DTU 1 is affixed to the diver's body in an appropriate location.
- ③ The diver dives in a predetermined maritime zone.
- ④ At the end of the dive, the DTU 1 is removed and mounted again in the mounting unit 21 of the check-in unit 2, and the end button 22 is pressed.
- ⑤ The DTU 1 is connected to the data analysis device 3 and data analysis is performed.

For each of the above procedures, more specific operations and the function of each part of the system are as follows:

[0022] ① Initiation of data recording by the DTU 1

When the DTU 1 is mounted in the mounting unit 21 of the check-in unit 2 at the departure point and the start button 22 is pressed, this activation of the start button 22 sets current time data from the check-in unit 2 to the timer 20 of the DTU 1 , after which the semiconductor memory 9 in the DTU 1 and all variables needed for data collection are initialized, all subsequent data being stored in the semiconductor memory 9 as certified data.

[0023] ② Storage of the diver's movement data during a dive by the DTU 1

(1) First, the diver's movement distance is calculated as follows. Output from the acceleration sensor 10 is obtained of changes in movement speed or acceleration in the movement direction relative to the immediately preceding position and is then passed through the double integrator 11, subjected to A/D conversion by the A/D converter 12, acquired at a fixed sampling period, and recorded in the memory with the relative time from the starting point added. This data indicates the distance moved from the position at the previous unit of time. .

[0024] What is important here is that since the semiconductor memory 9 is created for portable use and the memory capacity thereof is finite, in order to effectively utilize this limited memory capacity, it is necessary to record the maximum amount of significant data. In this embodiment, only the detection output of the acceleration sensor 10 outside a preset micro value range for this purpose are recorded in the semiconductor memory 9.

[0025] In other words, the CPU 17 does not record to the semiconductor memory 9 any output of the sensors 10 and 13 that has a 0 value or any micro data whose value is equal to or less than a preset value, recording to the semiconductor memory 9 only when the output exceeds the preset values in the next sampling cycle, thereby avoiding unnecessary data recording and ensuring effective collection of significant data only.

[0026] An example is shown in Figure 4. In this drawing, when the diver is at point P in an underwater 3D coordinate system at time t_0 and moves a very small distance ΔL to reach point Q at time t_1 after a minute of time Δt has elapsed, looking at the X-direction component Δx of the movement distance ΔL ,

the elapsed time Δt is defined as

$$\Delta t = t_1 - t_0$$

the amount of change in speed in X direction ΔV_x is expressed as

$$\Delta V_x = \Delta x / \Delta t$$

and the acceleration α_x in the X direction is expressed as

$$\alpha_x = \Delta V_x / \Delta t.$$

[0027]

[Table 1]

Changes in time	t_0	t_1	t_2	t_3	t_4	t_5	t_6	t_7	t_8
Output of accelerometer	0	+1	+1	0	+2	0	-2	-1	-1
Speed	0	1	2	2	4	4	2	1	0
Position	0	1	3	5	9	13	15	16	17

[0028] Therefore, by integrating the data obtained chronologically from the acceleration sensor, the change in speed can be calculated, and by integrating this over time, the movement distance can be calculated. For example, as shown in Table 1, assuming that the output from the acceleration detection unit 6 changes every unit of time due to movement of the diver who is stationary at the point of origin (X coordinate: 0) at time t_0 , and then calculating the position from the point of origin, the results shown in the table can be obtained. Only the movement components in the X-direction are shown, but the same process can be used to calculate the components in Y- and Z-directions as well.

[0029] (2) Next, the diver's movement direction is calculated as follows. Output from the gyroscope 13 is obtained for rotation relative to the previous position, subjected to A/D conversion at a fixed sampling period, and imported into the CPU as a digital value to calculate the change in the diver's movement direction.

[0030] Assuming that the diver rotates underwater $\Delta\theta_{xy}$ in the X-Y plane during the time Δt ,

the angular rate $\Delta\omega_{xy}$ in the X-Y plane is expressed as

$$\Delta\omega_{xy} = \Delta\theta / \Delta t.$$

Therefore, the angle of rotation (change in movement direction) can be calculated by using with the integrator 14 to integrate the data obtained chronologically from the gyroscope over time.

[0031] In this case, in order to effectively utilize the limited memory capacity of the semiconductor memory 9, only values detected by the gyroscope 13 outside the preset micro value range is recorded in the semiconductor memory 9.

[0032] The coordinates of the diver's current position can be obtained by integrating the output of the acceleration detection unit 6 and the angular velocity detection unit 7 described above.

[0033] ③ Ending diver data recording by the DTU 1

At the end of the dive, when the DTU 1 is mounted in the mounting unit 21 of the check-in unit 2 and the end button 23 is pressed, this activation of the end button 23 finalizes the data recorded in the DTU 1 and the data recording by the DTU 1 is stopped after that.

[0034] ④ Data analysis by the data analysis device 3 and calculation of diver position coordinates
The data analysis device 3 sequentially reads out the dive data that has been recorded chronologically in the semiconductor memory 9 of the DTU 1 and processes the data.

(1) First, the departure point is determined using the initial data recorded in the semiconductor memory 9 as location where the check-in unit 2 is installed, so this is used as the point of origin, i.e., the departure point.

(2) Next, the position coordinates of movement are calculated by analyzing the data recorded in the semiconductor data 9 together with the relative elapsed time and calculating the 3D path as values in the coordinate system.

[0035] The full dive path obtained by analyzing the data collected in the semiconductor memory 9 of the DTU 1 is displayed and reproduced chronologically and dynamically on the 3D map in the display of the reproduction device 4, and a student diver can receive guidance from an instructor while viewing the screen.

[0036] The foregoing embodiment describes use of the DTU 1 as part of a diving training system, but it goes without saying that the DTU 1 is applicable to various other fields where it is necessary to identify movement paths of various underwater moving bodies.

[0037]

[Effects of the Invention] As explained above, with the mobile data collection device for an underwater moving body of the present invention, data detected using a 3D acceleration sensor and a 3D gyroscope can be recorded in a semiconductor memory in order to accurately track the 3D movement path of an underwater moving body.

[0038] In addition, the detection output from the acceleration sensor and the gyroscope are recorded in the semiconductor memory as 3D movement data of the moving body during underwater movement, except when the values detected by the acceleration sensor and the gyroscope do not exceed a preset micro value range, so that only significant data in the movement detection values of an underwater moving body is recorded in the semiconductor memory. Therefore, while the device can be made small and compact, it is possible to record underwater path data over relatively long periods of time.

[0039] With Claim 2, the main body of the mobile data collection device for an underwater moving body can be easily worn by a diver, and accordingly does not interfere with swimming while diving and can be used effectively during diving training and so on.

[0040] With Claim 3, the 3D movement data necessary to graphically represent the 3D path after a dive can be recorded chronologically together with the time at which the data was provided, and therefore the 3D movement data necessary to graphically represent the 3D path after a dive is recorded chronologically together with the time at which the data was provided, meaning that not only is the data very accurate, but the diver's underwater path can be faithfully reproduced as well.

[0041] With the diving training system according to Claim 4, the system comprises a mobile data collection device for an underwater moving body, a data analysis device that can be electrically connected to the mobile data collection device and analyzes the 3D movement data recorded by the control means of the mobile data collection device, and a reproduction device for displaying and reproducing chronologically and dynamically a full dive path on a 3D map based on the processed data from the data analysis device. Therefore, data acquired by the mobile data collection device can be analytically processed as certified significant data, and the full dive path can be displayed and reproduced chronologically and dynamically on the 3D map based on the processed data.

[0042] Thus, the present invention can realize a portable, user-friendly and inexpensive collection device, provide a diving training system capable of accurately reproducing a movement path using computer data analysis after a dive, and provides the advantageous effect of displaying the diver's dive path on a display or drawing accurately, which was impossible before now.

[BRIEF DESCRIPTION OF THE DRAWINGS]

[Figure 1] Figure 1 is a block diagram showing a general configuration of a diving training system according to an embodiment of the present invention.

[Figure 2] Figure 2 is a schematic side view of a DTU and a check-in unit.

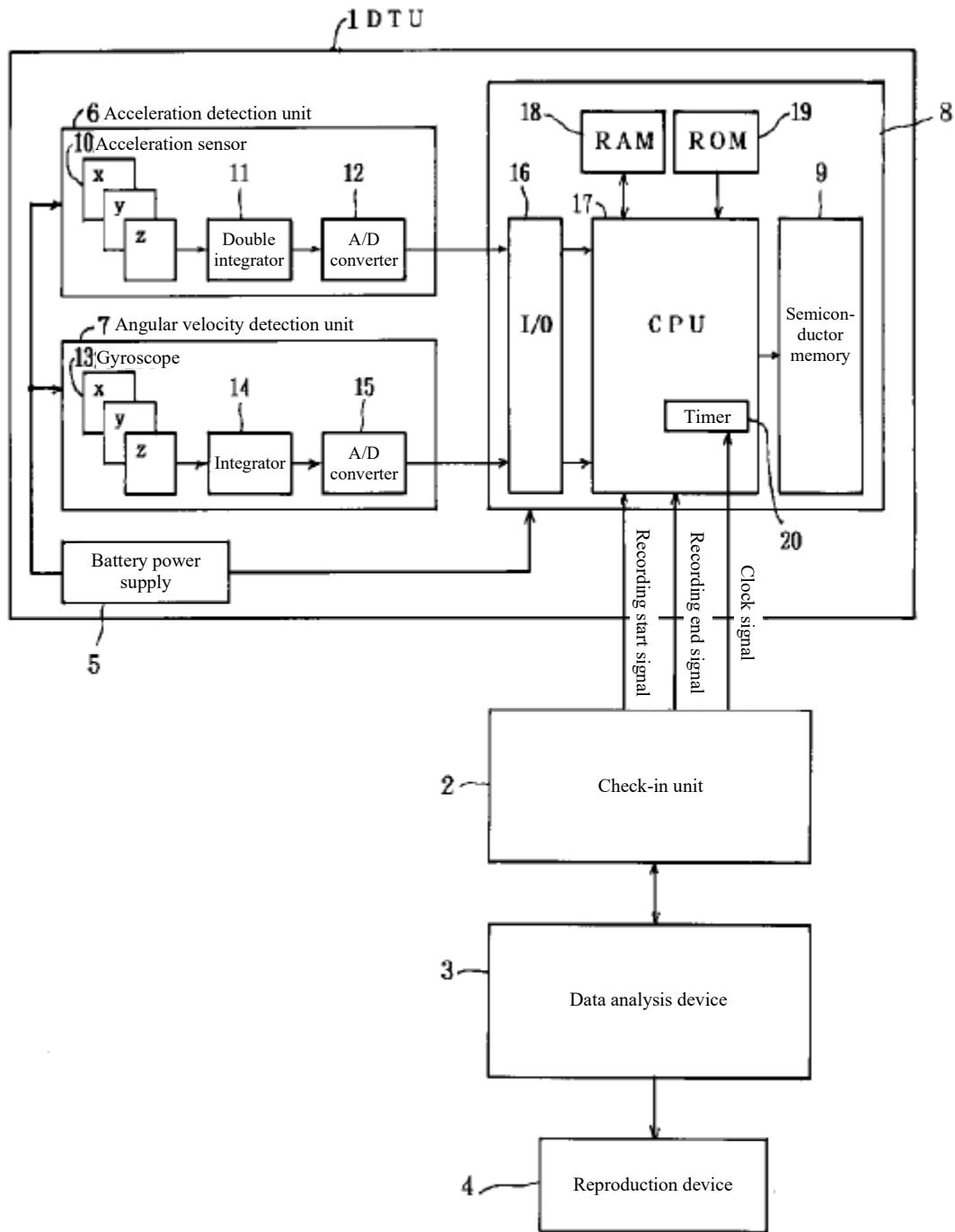
[Figure 3] Figure 3 is a plan view of Figure 2.

[Figure 4] Figure 4 is a schematic diagram for describing calculation of a diver's movement distance.

[Description of Codes]

- 1 DTU
- 1a Device body
- 2 Check-in unit
- 3 Data analysis device
- 4 Reproduction device
- 5 Battery power supply
- 6 Acceleration detection unit
- 7 Angular velocity detection unit
- 8 Intelligent computer
- 9 Semiconductor memory
- 10 3D acceleration sensor
- 13 3D gyroscope
- 20 Timer

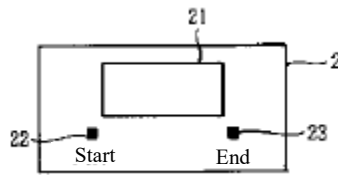
[FIGURE 1]



[FIGURE 2]



[FIGURE 3]



[FIGURE 4]

